MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2022/2023 (TERM ID 2220)

EEL2066 – ELECTRICAL ENGINEERING MATERIALS

(All sections / Groups)

11 JULY 2023
9:00 am – 11:00 pm
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 7 pages with 4 questions only.

2. Answer all **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

Calculate the coordination number, atoms per unit cell, the atomic radius (R) to lattice constant (a) ratio, and the atomic packing factor (APF) for the following structures respectively:

a) simple cubic [8 marks]

b) face centered cubic (FCC) [8 marks]

c) body centered cubic (BCC) [9 marks]

Question 2

a) State **THREE** types resistivity scatterer. [3 marks]

b) A hypothetical element with electrical resistivity $\rho_{300} = 2.72 \times 10^{-8}$ Ωm at 27 °C, coefficient of thermal resistivity $\alpha_{273} = 4.29 \times 10^{-3}$ K^{-1} at 0 °C, density = 2700 kgm^{-3}, atomic mass = 0.027 kg and valence electron = 3. Calculate:

i) its resistivity, ρ at a temperature of -40 °C. [6 marks]

ii) the thermal coefficient, α of resistivity at -40 °C. [5 marks]

iii) the number of electrons per unit volume, n. [3 marks]

iv) the mean free time between collision, τ. [3 marks]

c) A 4 mm diameter wire carrying 13 A of current with maximum voltage drop of 0.02 V for every 333 mm in length. Calculate the minimum electrical conductivity of the wire. [5 marks]

Continued ...

Question 3

a) A parallel plate capacitor with cross section area of 5×10^{-4} m^2, plate separation of 2 mm and dielectric constant, ε_r of 4 is designed to work in the medium to high frequency range. If a potential of 10 V is applied, determine:

i) it's capacitance, C [2 marks]

ii) amount of charge stored, Q [2 marks]

iii) dielectric displacement value, D [2 marks]

iv) polarization value, P [2 marks]

v) if the capacitor is still able to function if the dielectric material is replaced with air? Explain your answer. [2 marks]

b) State the type(s) of polarization(s) involved in the following ranges of-frequencies:

i) radio frequency [3 marks]

ii) infrared [2 marks]

iii) ultraviolet [1 mark]

c) A 0.25 m long coil of wire with 400 turns carries 15 A of current. Calculate the following:

i) magnetic field strength, H [2 marks]

ii) flux density, B, if the coil is under vacuum condition. [2 marks]

iii) flux density, B, and magnetization, M if the coil has bar of chromium positioned within the coil. [5 marks]

It is given that the susceptibility of chromium, χ_m, 3.13×10^{-4}.

Continued ...

Question 4

a) Determine:

i) the maximum energy gap (in eV) that a semiconductor, when used as a photoconductor, should have if it is to be sensitive to yellow light (λ = 600 nm). [2 marks]

ii) the power of a photodetector with an area of 5×10^{-2} cm^2 which is irradiated with yellow light whose intensity is 2 mW cm^{-2}. [2 marks]

iii) the number of electron-hole pairs generated per second from part (ii). Assume that each photon generates one electron-hole pair. [3 marks]

iv) the primary wavelength of photons emitted from galium arsenide (GaAs) (E_g = 1.42 eV). Is the wavelength visible? [4 marks]

v) if a silicon (E_g = 1.1 eV) photodetector would be sensitive to the radiation from a GaAs laser. Explain your answer. [4 marks]

b) Calculate the intrinsic electrical conductivity of GaAs at the following temperatures:

i) room temperature, 27 °C [3 marks]

ii) 70 °C [7 marks]

End of Paper

Appendix

Physical Constants

Electron charge	e	1.60×10^{-19} C
Electron mass	m_e	9.11×10^{-31} kg
Permittivity of free space	ε_0	8.85×10^{-12} F/m
Permeability of free space	μ_0	1.26×10^{-6} H/m
		$4\pi \times 10^{-7}$ H/m
Bohr Magneton	μ_B	9.27×10^{-24} Am^2
Avogadro's number	N_A	6.023×10^{23} molecules/mol
Planck's constant	h	6.63×10^{-34} Js^{-1}
Boltzmann's constant	k	1.38×10^{-23} J(atom.K)$^{-1}$
		8.62×10^{-5} eV(atom.K)$^{-1}$

Formulae

Coulomb's Force

$$F = \frac{1}{4\pi\varepsilon_r\varepsilon_0}\frac{Q_1Q_2}{R^2}$$

Electron per unit volume

$$n_E = \frac{N_A d}{M_{atomic}}$$

Density

$$\rho = \frac{nA}{V_c N_A}$$

Equilibrium number of vacancies

$$N_v = N\exp\left(-\frac{Q_v}{kT}\right)$$

Hall voltage

$$V_H = \frac{R_H I_x B_z}{d}$$

$$R_H = -\frac{\mu_e}{\sigma}$$

$$R_H = \frac{1}{ne}$$

Clausius – Mossoti Equation

$$\frac{N\alpha_e}{3\varepsilon_o} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

Electric field (localized)

$$E_{loc} = E + \frac{P}{3\varepsilon_0}$$

Conductivity

$$\sigma = ne\mu_e + np\mu_h$$

$$\sigma = \sigma_0 e^{\frac{E_g}{2kT}}$$

$$\sigma = \frac{1}{\rho} = \frac{e^2 n\tau}{m_e}$$

Resonance frequency

$$\omega_0 = \left[\frac{Ze^2}{m_e\alpha_e}\right]^{\frac{1}{2}}$$

Temperature dependent resistivity

$$\rho = \rho_0\left[1 + \alpha_0(T - T_0)\right]$$

Ohm's Law

$$V = IR$$

Resistivity

$$R = \rho\frac{L}{A}$$

Photon energy $E_{ph} = h\frac{c}{\lambda}$

Polarization $P_e = \chi_e \varepsilon_0 E = (\varepsilon_r - 1)\varepsilon_0 E$

$$\omega_o = \left(\frac{Ze^2}{m_e \alpha_e}\right)^{\frac{1}{2}}$$

Drift velocity $\mu_d = \mu_e E$

$$\mu_d = \frac{e\tau}{m_e}$$

Mean free path $\ell = \mu\tau$

Mean free time between collision $\tau = \frac{m_e}{\rho e^2 n}$

Electric dipole moment $p = qd$

Dielectric displacement $D = \varepsilon_r \varepsilon_0 E$

$Q = CV$

$D = \varepsilon_0 E + P$]

Capacitance $C = \varepsilon_r \varepsilon_0 \frac{A}{L}$

Magnetism of materials $H = \frac{NI}{L}$

$M_s = \mu_d N$

$M_s = \mu_d N = N'\mu_B = \frac{n_B \mu_B}{a^3}$

$N' = \frac{n_B}{a^3}$

$B_s = \mu_o M_s$

$B = B_0 + \mu_0 M$

$M = \chi_m H$

Saturation magnetization

$$M_s = \left[\frac{\text{atoms}}{\text{volume}}\right]\left[\frac{\text{No of Bohr Magnetons}}{\text{atom}}\right]\left[\text{Bohr Magneton Constant}\right]$$

$$M_s = \frac{\left[\text{atoms per unit cell}\right]\left[\text{No of Bohr Magneton}\right]\left[\text{Bohr Magneton Constant}\right]}{\left[\text{volume per unit cell}\right]}$$

Conductivity $C = \ln\sigma + \frac{E_g}{2kT}$

Irradiated power $P_{\text{irradiated}} = (\text{Area}) \times (\text{Intensity}) = AI_{\text{light}}$

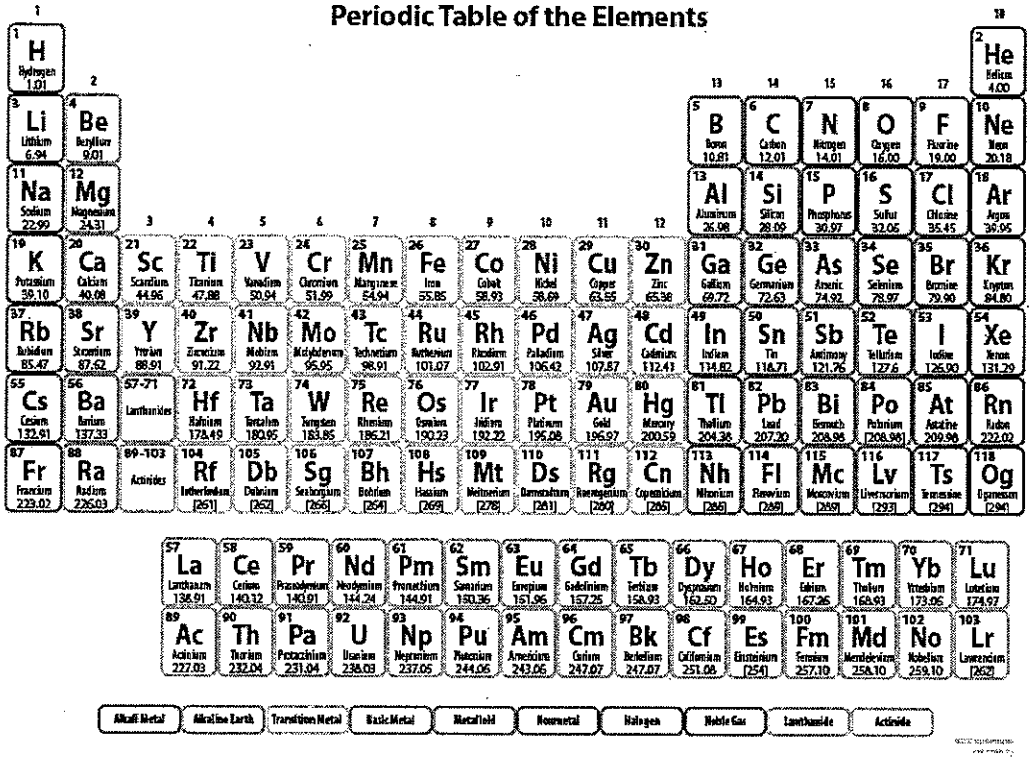
Photons count $N = \frac{\text{Irradiated Power}}{\text{Photon Energy}} = \frac{P_{\text{irradiated}}}{E}$

Current density $J = \frac{I}{A}$

Electric power $P = IV$

Electric field $$E = \frac{V}{L}$$

$$number\ of\ electron - hole\ pair = \frac{power}{E_{ph}}$$



End of Appendix